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Altitudinal and depth wise variation of physico-chemical properties, macronutrient status of soil and leaf and their correlation studies of HDP apple orchards under MM 106 rootstock of north Kashmir

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Abstract
Apple (*Malus domestica* Borkh.) one of the rosaceous group is native of Asia Minor to western Himalayas. High density apple orchards developed on semi dwarf rootstock like MM 106 have become common in many apple growing regions of the Kashmir especially North Kashmir. Suitability of soil as a medium of plant growth depends on both its physico-chemical properties and nutritional status. As per the results soils were slightly acidic to slightly alkaline and ranged statically from 6.55 to 7.52 in surface and 7.31 to 7.78 in sub-surface soils. The highest values of organic carbon in surface and sub-surface soils were found in orchards located in high altitude followed by mid and low altitudes orchard soils. The available nitrogen, phosphorus and potassium content varied significantly with altitude and the higher values were observed in HDP apple orchards located in high altitude. The available nitrogen and phosphorus showed a decreasing trend while as available potassium showed irregular with soil depth. The foliar contents of nitrogen, phosphorus and potassium in high density apple were found to be sufficient. The leaf calcium, magnesium and sulphur varied from 1.66 to 1.75, 0.27 to 0.31, and 0.20 to 0.23 per cent respectively. Significantly higher average yield was recorded in high and mid altitudes than low altitude HDP apple orchards. Nutrients showed positive relation with organic carbon. Plants absorb nutrients from both surface as well as sub-surface soils. The present study though first of its kind on high density apple orchards is expected to be quite useful for horticulturists for formulation of future research programme.

Keywords: High density, macronutrient, depth, correlation, Kashmir

Introduction
Walter R. Lawrence (1895) cited that “Kashmir is the country of fruits” and perhaps no country has greater facilities for horticulture, as the indigenous apples, pear, vine, mulberry, walnut, hazel, cherry, peach, apricot, strawberry, raspberry and can be obtained without any difficulty in most parts of the valley. However, the geographical terrain and climate also create disadvantages for the state in terms of connectivity and other factors (Zahoor, 2013) [60].

Apple cultivation in J&K is fast expanding because apple has a comparative advantage over the other crops that can be grown in hilly regions. High density apple orchards developed on dwarfing rootstocks like M 9, M 26 and MM 106 have become common in many apple growing regions of the Kashmir. However, in most of the apple orchards semi dwarf root stock (MM 106) is used. High yield and high fruit quality can be achieved with a high-density orchard when the orchard has good light distribution throughout the tree canopy and there is a balance between vegetative growth and cropping (“calm trees”). However, plant growth, yield and fruit quality are directly influenced by many factors *viz*. environmental conditions, orchard management and equally influence the nutritional status of the tree. Since various high density apple orchards with different varieties have been planted on different dwarf and semi-dwarf rootstocks to boost the apple production in Kashmir valley particularly in north Kashmir which is the major apple growing area and scanty information is available with respect to high density apple cultivation. North Kashmir is an important part of Kashmir valley (Fig. 1) with respect to the agricultural perspective consists of mainly three districts namely district Kupwara, Baramulla and Bandipora. The districts are situated between 34˚ 13′ 53.3″ N to 34˚ 25′ 48.2″ N Latitude and 74˚ 19′ 38.1″ E to74˚ 40′ 01.8″ E Longitude with a mean elevation of about 1642 m amsl. It contributes a total geographical area of India-administrated Jammu and Kashmir 101,387 km^2 out of which Kashmir has 15,948 km^2 with district Kupwara 2,379 km^2 district Baramulla 4,588 km^2 district Bandipora 398 km^2 (Anonymous, 2016).

The total area under apple in Jammu and Kashmir is 162.97 thousand hectares with production 1726.83 MT and productivity with 10.60 MT ha^{-1} (Singh *et al.*, 2017). Area under apple plantation in Kashmir is 1,43,534 hectares with 16,33,349 MT production, out of which district Kupwara has 18,981 with production 2,83,444 mt, Baramulla 24,675 hectares area, with production 5,10,766 MT, Bandipora having 5,840 hectares area having production of about 69,147 MT **(**Akmali, 2018).

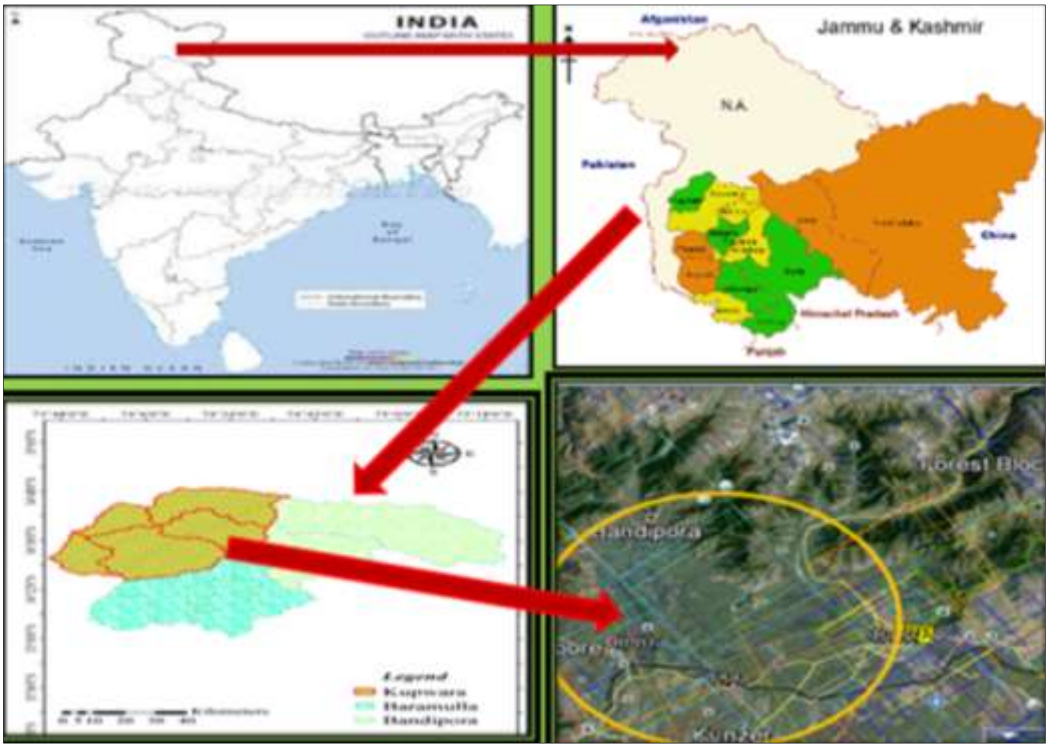

Fig 1: Location map of study area (North Kashmir)

Proper understanding of physico-chemical characteristics of soil gives greater insight of the dynamics of the soil. Despite increase in the study of physico-chemical characterization of certain soils within state of Jammu and Kashmir (Wani *et al.*, 2009) [56] during the past few decades, but no information is available on the impact of these changes on the diverse soils of HDP apple of the region.

Nutritional imbalance in the soil causes nutritional disorders and consequently affects both the quality and quantity of fruit, in addition the plants become more susceptible to disease and pests. Hillel (1980) [19] stated that suitability of soil as a medium of plant growth depends on both its chemical and physical properties. The nutrient supplying power of a soil depends on dissociation of the nutrients from the exchange site, which is in turn depend on the degree of saturation of the nutrients on the exchange site, type of clay and complementary ion-effect (Foth and Ellis, 1997) [17]. Continued removal of nutrients, with little or no replacement has aggravated the potential for future nutrient related plant stress and yield loss. Therefore, evaluating the fertility status of a soil is important to know the productivity of a soil. Soil fertility and plant nutrition are two closely related subjects that emphasize the forms and availability of nutrients in soils, their movement and uptake by roots and the utilization within the plants. The soil and plant analysis are complimentary to each other because at times one will supply the information that the other may not therefore, it is advisable to consider analysis of both the components in assessing the nutritional status of fruit crops especially those fruit crops where the plants have deep and ramified root system, thus provides a valuable tool for understanding the nutrient supplying capacity of soil for ascertaining the relationship between available soil nutrient content and leaf nutrient status and therefore predicting the yield levels. Besides, knowledge of nutrient distribution down the profile is important to evaluate the contribution of different sub-surface soil horizons. Therefore, the studies on “Altitudinal and depth wise variation of physico-chemical properties, macronutrient status of soil and leaf and their correlation studies of hdp apple orchards under MM 106 rootstock of north Kashmir” is essential to generate information regarding soil characteristics and nutrient indexing of apple growing orchards and standardize site-specific technologies to improve the yield. Besides, the information can be utilized for framing the fertilizer recommendations. The information would be useful for the subsequent research and developmental activities and shall guide in assessing the possible cause of low yield and quality fruit production.

Material Methods

1. Selection of profile sites

Keeping in view the surface features, forty five (45) soil profiles were observed (Fig. 2) in high density apple orchards at different locations of north Kashmirin the year 2017-2018. Based on uniformity like age, topography, rootstock, variety only twelve (12) profiles were selected from forty five (45) observed profiles (purposive method of sampling) and these twelve profiles were categorised into high, mid and low altitudes for studying the soil properties.

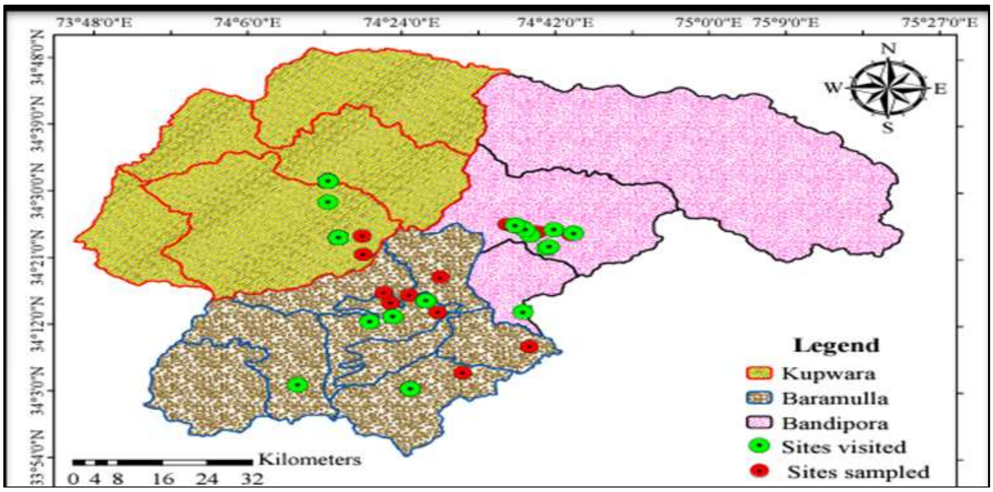

Fig 2: Map showing observed sites under HDP apple orchards of north Kashmir

2. Collection of soil samples

Soil samples were collected from various depths at an interval of 30 cm up to the depth of 90 cm from the selected 12 high density apple orchards (Fig. 3) located in North Kashmir of three districts (Bandipora, Baramulla and Kupwara) and from each orchard, samples were made from representative profile of each orchard for each layer up to depth of 90 cm (0-30, 30-60, 60-90 cm) for laboratory investigation.

Fig 3: Soil and leaf sampling of HDP apple orchards in North Kashmir

3. Methods of laboratory analysis

The soil samples collected from different layers of the studied soil profiles were brought to the laboratory, air dried and grounded in a wooden pestle and mortar. Ambient soil was passed through 2 mm sieve to separate the coarse fragments and then subjected to laboratory analysis.

A. Physiochemical properties

The pH of soil sample was determined in 1:2.5 soil: water suspension with the help of glass electrode pH meter as described by Jackson (1973) [21]. The electrical conductivity of soil water extract was read with the help of conductivity meter (Jackson, 1973) [21]. Organic carbon was determined by chromic acid wet digestion method as outlined by Wakley and Black (1934) [53]. Estimation of calcium carbonate was done by rapid titration method as described by Piper (1966).

B. Available macro-nutrients

Available nitrogen was estimated by alkaline permagnate method as given by Subbiah and Asija (1956) [49]. The available phosphorus was extracted by 0.5 M $NaHCO_3$ at pH 8.5 and colour developed by stannous chloride and measured with the help of spectrophotometer at 660 nm wave length (Olsen and Sommers, 1982) [41]. The available potassium was extracted by 1N ammonium acetate at pH 7 and then determined with the help of flame photometer (Jackson, 1973) [21]. The available calcium was determined by versenate titration method after extraction with ammonium acetate solution (Black, 1965) [53]. The available magnesium was extracted with ammonium acetate and estimated by versenate titration method given by Black (1965) [53]. Available sulphur was determined turbidimetrically as Barium sulphate using the method of Chesnin and Yein (1950) [10]. Weighed quantity of soil was treated with sodium acetate-acetic acid buffer and later turbidity was developed by $BaCl_2$ crystals and reading was taken by spectrophotometer at wave length of 420 nm.

4. Collection and preparation of leaf samples

Leaf samples as per the procedure of Chapman (1964) [9] and Waller (1980) were collected from current year growth of the selected high density apple orchards and analysed for their mineral content**.** After collection samples were washed with tap water and later dipped in dilute hydrochloric acid. Further washings were repeated with single and double distilled water. The samples were air dried on filter papers and then oven dried at 60±5ºC for 24 hours (Chapman, 1964) [9]. The samples were then ground in a stainless steel blender to pass through 2 mm mesh and stored in polythene bags for subsequent analysis.

5. Digestion of leaf samples

Nitrogen in leaf samples was determined by digesting the samples in concentrated sulphuric acid in presence of digestion mixture comprising of potassium sulphate, copper sulphate, iron sulphate and selenium powder in the ratio of 10.0: 0.5: 1.0: 0.1. For the determination of phosphorus, potassium, calcium, magnesium, sulphur the leaf samples were digested separately in diacid mixture of nitric acid and perchloric acid in the ratio of 10:3. The digested material was diluted in double distilled water and filtered in 100 ml volumetric flask. In order to ensure complete transfer of digested material, about six washings were given with double distilled water and final volume was made to 100 ml.

6. Chemical analysis of leaf samples

The nitrogen was estimated by Micro-kjeldahl's distillation method as described by Jackson (1973) [21]. Phosphorus was determined by vanadomolybedo phosphoric acid yellow colour method as outlined by Jackson (1973) [21]. Potassium in the extract was determined on flame photometer described by Jackson (1973) [21]. Calcium and magnesium were estimated by versenate titration method given by Jackson (1973) [21]. Sulphur in the extract was determined by turbidity method given by Chesnin and Yien (1951) [10].

7. Fruit yield: Fruit yield from each orchard was recorded at the time of harvest.

8. Statistical analysis: The data was statistically analysed following the standard procedures outlined by Gomez and Gomez (1984). Coefficient of correlation (r-values) between the different soil (physico-chemical properties, available nutrients) and plant (leaf and yield) parameters was done using statistical software 'SPSS'.

Table 1: Critical limits of available nutrient elements in soils

Nutrient element	Unit	Soil fertility classes			Reference
		Low	Medium	High	
Organic carbon	%	<0.5	0.5-0.75	>0.75	Walkley and Black (1934) [53]
Nitrogen	kg ha^{-1}	<125	125-544	>544	Subbiah and Asija (1956) [49]
Phosphorus	kg ha^{-1}	<12	12-24	>24	Olsen *et al.* (1954) [41]
Potassium	kg ha^{-1}	<125	125-280	>280	Hanway and Heidal (1952) [48]
Calcium	ppm	<1000	>1000		
Magnesium	ppm				
Sulphur	ppm	<10	-	-	Kanwar and Mohan (1964) [23]

Table 2: Tentative working standards for apple (leaves)

Nutrient	Macro-nutrients (%)			
	Deficient	Low	Sufficient	High
Nitrogen	1.50	1.50-1.80	1.90-2.40	2.50
Phosphorus	0.14	0.15-0.18	0.18-0.28	0.30
Potassium	1.00	1.00-1.20	1.30-1.80	1.90
Calcium	1.00	1.00-1.20	1.30-1.90	1.80
Magnesium	0.20	0.20-0.24	0.24-0.36	0.37
Sulphur	<0.10	0.10-0.16	0.17-0.26	>0.26

Result and Discussion

Physico-chemical characteristics

The perusal of the data (Table 1) pertaining to various physico-chemical properties of composite soil samples collected from HDP apple orchards in three different altitudes of North Kashmir are presented as below.

Soil reaction (pH): The result revealed that the pH of surface soils of high, mid and low altitude varied (95% CI) from 6.29 to 7.01, 6.93 to 8.36 and 7.10 to 7.72 with mean value of 6.68, 7.65 and 7.40 respectively while as, in sub-surface soils it ranged from 6.66 to 6.91, 6.97 to 8.60 and 7.44 to 7.85 with mean value of 6.79, 7.69 and 7.65 respectively. The soil pH showed significant variation with altitude and lowest mean pH value (6.68) was recorded in high altitude soils. In general pH increased with depth from surface to sub surface and was found slightly acidic to slightly alkaline in nature. This variation of pH in the soils of three altitudes could be attributed to leaching of bases due to high rainfall or higher precipitation level and variations in organic matter as well as temperature gradient. Similar observations were reported by Najar *et al.* (2006) [39], Naik (2016). It was observed that the soil pH increased with an increase in depth, which may be due to declining trend of organic matter accumulation with depth, leaching of basic cations from surface to sub-surface horizons. Similar results were noticed by Naik (2014) and Wani *et al.* (2017) [6].

Table 1: Physico-chemical properties of High density Apple orchard soils of north Kashmir

Profile	Depth (cm)	pH (1:2.5)	EC (dSm^{-1})	OC (%)	$CaCO_3$ (%)
1	3	4	5	6	7
P_1	0-30	6.68	0.23	1.51	0
	30-60	6.80	0.31	0.70	0
	60-90	6.78	0.41	0.55	0
Surface	Mean	6.68	0.23	1.51	0
	95% CI	6.29-7.01	0.01-0.29	0.05-2.45	0
Sub-surface	Mean	6.79	0.36	0.62	0
	95% CI	6.66-6.91	0.02-0.99	0.03-1.57	0
P_2	0-30	7.20	0.33	1.21	0
	30-60	7.18	0.37	0.56	0

	60-90	7.32	0.30	0.51	0
P_3	0-30	8.10	0.40	1.05	1.11
	30-60	8.45	0.44	0.65	1.30
	60-90	7.82	0.45	0.50	1.27
Surface	Mean	7.65	0.36	1.13	0.55
	95% CI	6.93-8..36	0.07-0.80	0.01-2.14	0.04-1.60
Sub-surface	Mean	7.69	0.39	0.55	0.64
	95% CI	6.97-8.60	0.27-0.50	0.44-0.66	0.05-1.82
P_4	0-30	7.2	0.30	1.15	0
	30-60	7.3	0.33	0.71	0
	60-90	7.5	0.39	0.52	0
P_5	0-30	7.3	0.29	1.11	0
	30-60	7.5	0.30	0.67	0
	60-90	7.4	0.32	0.60	0
P_6	0-30	7.2	0.24	0.98	0
	30-60	7.5	0.25	0.62	0
	60-90	7.6	0.27	0.48	0
P_7	0-30	8.2	0.38	1.10	0.55
	30-60	8.3	0.41	0.71	0.73
	60-90	8.4	0.44	0.56	1.21
P_8	0-30	7.5	0.19	0.97	0
	30-60	7.6	0.21	0.74	0
	60-90	7.7	0.28	0.56	0
P_9	0-30	7.2	0.21	1.12	0
	30-60	7.4	0.30	0.82	0
	60-90	7.3	0.32	0.55	0
P_{10}	0-30	7.9	0.31	1.14	0.35
	30-60	8.3	0.35	0.80	0.47
	60-90	8.4	0.42	0.50	0.80
P_{11}	0-30	7.1	0.25	1.13	0
	30-60	7.2	0.27	0.73	0
	60-90	7.3	0.31	0.51	0
P_{12}	0-30	7.3	0.20	0.96	0
	30-60	7.6	0.24	0.55	0
	60-90	7.4	0.31	0.48	0
Surface	Mean	7.4	0.26	1.07	0.10
	95% CI	7.10-7.72	0.21-0.31	1.01-1.13	0.05-0.25
Sub-surface	Mean	7.65	0.31	0.61	0.17
	95% CI	7.44-7.85	0.28-0.34	0.56-0.67	0.004-0.36
Surface	Mean	7.24	0.28	1.236667	0.216667
	95% CI	6.55-7.52	0.20-0.31	1.04-2.00	0.11-0.32
Sub-surface	Mean	7.37	0.35	0.593333	0.27
	95% CI	7.31-7.78	0.30-0.39	0.56-0.65	0.04-0.43
Surface / Sub-surface	C.D ($p \leq 0.05$)	0.08	0.04	0.16	0.06

CI = Confidence interval, C.D = Critical deference

Electrical conductivity (EC)

Presented in Table-1 indicated that electrical conductivity in surface soils of high, mid and low altitude varied (95% CI) from 0.01 to 0.29, 0.07 to 0.80 and 0.21 to 0.31 dSm^{-1} with mean value of 0.23, 0.36 and 0.26 dSm^{-1} respectively, while as it ranged (95% CI) from 0.02 to 0.99, 0.27 to 0.50 and 0.28 to 0.34 dSm^{-1} with mean value of 0.36, 0.39 and 0.31 dSm^{-1} in sub-surface soils of high, mid and low altitude, respectively. The highest mean values of EC in surface and sub-surface soils (0.36 and 0.39 dSm^{-1}) were observed in the mid altitude. In general, electrical conductivity of all soil depths were observed normal. These results are in agreement with those of Najar (2002) [37] and Dar (2012) [12] while working on apple orchard soils of Kashmir. The relatively lower value of electrical conductivity in surface soils of high, mid and low altitude soils could be due to leaching of soluble salts from surface to sub-surface soils and runoff transportation due to high precipitation rates. The electrical conductivity showed an erratic trend with an increase in soil depth however significantly higher electrical conductivity was recorded in sub-surface soils. This is in accordance with the findings of Tuba and Kaleem (2016) [51].

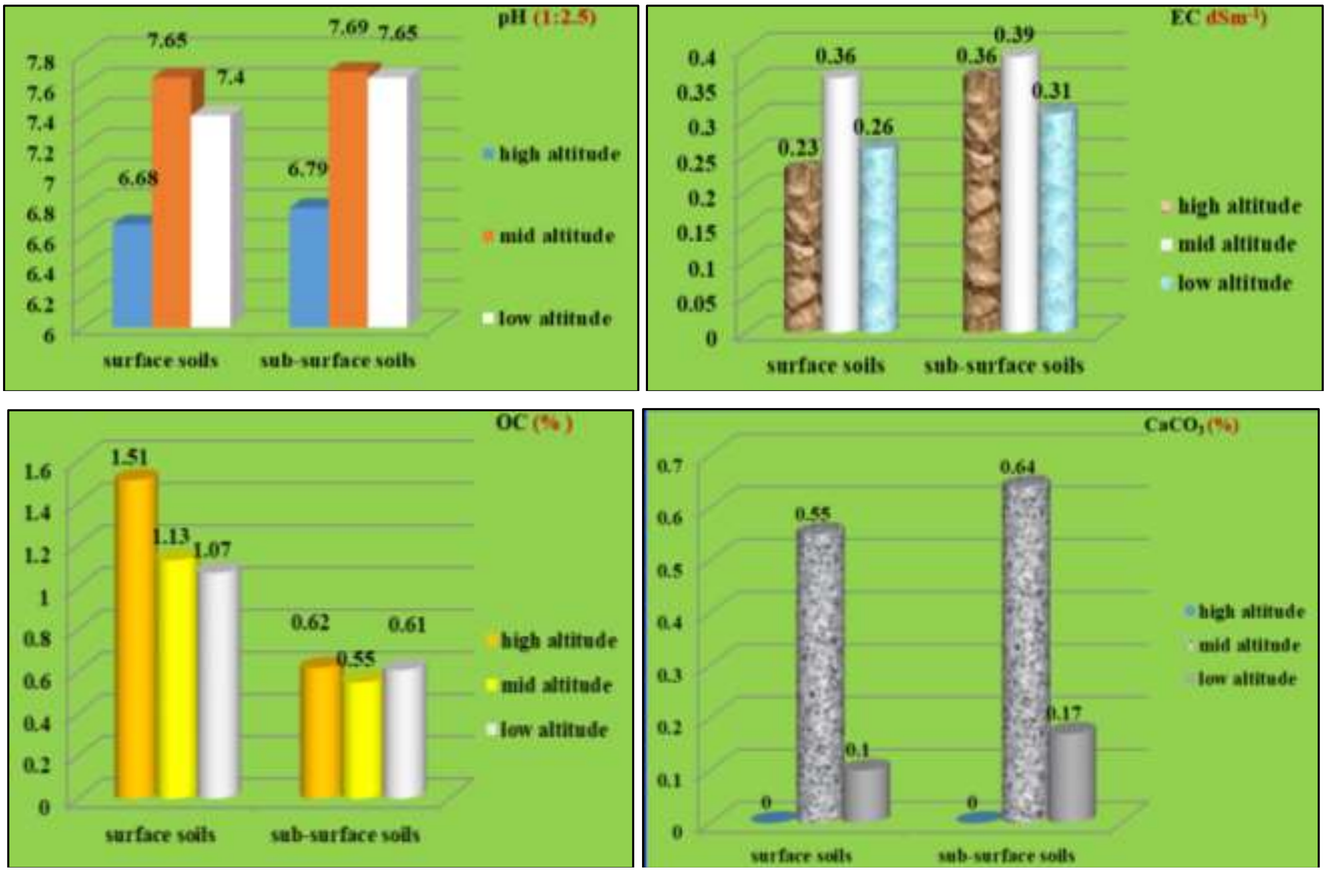

Fig 4: Graphical representation of Physico-chemical properties of High density Apple orchard soils of north Kashmir

Organic carbon (OC)

The organic carbon content in the surface soils of high, mid and low altitude ranged (95% CI) from 0.05 to 2.45, 1.01 to 2.14 and 1.01 to 1.13 per cent with mean value of 1.51, 1.13 and 1.07 per cent respectively, while as it ranged (95% CI) from 0.03 to 1.57, 0.44 to 0.66 and 0.56 to 0.67 per cent with mean value of 0.62, 0.55 and 0.61 per cent in sub-surface soils of high, mid and low altitude, respectively (Table-1). The surface soils showed higher levels of organic carbon content which decreased with increase in soil depth irrespective of its physiography. This may be attributed to continuous organic manuring and addition of organic matter through vegetation and its bio recycling and low mineralization rates due to low temperature. The results were corroborating with the findings of Sharma *et al.* (2005) [45] and Najar *et al.* (2009) [38]. The organic carbon content varied with the altitude and relatively higher amount of organic carbon was observed in the soils of high altitude which could be attributed to low temperature and high rainfall favouring luxurious vegetation and increase in soil acidity that favours low rate of decomposition or mineralisation leading to consequent accumulation of organic matter in these soils. On the other hand, the lower amounts of organic carbon content observed in the soils of lower altitude may be due to surface tillage operations by which the organic carbon/matter build-up would be low especially under continuous cultivation. Similar results were earlier reported by Tan *et al.* (2004) and Wani *et al.* (2016) [54].

Calcium carbonate ($CaCO_3$)

As shown in Table-1, the calcium carbonate was present in meager amounts in most of the orchards. The calcium carbonate content ranged (95% CI) from 0.04 to 1.60 and 0.05 to 0.25 per cent with mean values of 0.55 and 0.10 per cent in the surface layer and from 0.05 to 1.82 and 0.04 to 0.36 per cent with mean values of 0.64 and 0.17 per cent in sub-surface layer in mid and low altitude respectively, while as high altitude orchards were devoid of calcium carbonate. The calcium carbonate showed an increasing trend with an increase in soil depth. Higher amounts of calcium carbonate were recorded in sub-surface horizons than in surface horizons. The higher contents observed in mid altitude orchards indicates the calcareous nature of these soils. Similar observations were earlier reported by Khanday (2013) [24], Tuba and Kaleem (2016) [51]

Available macro-nutrients status of high density apple orchard soils

Available nitrogen (N)

The available nitrogen content in surface soils of the high, mid and low altitude varied with statistical range (95% CI) from 62.55 to 589.22, 290.83 to 474.95 and 323.66 to 371.83 kg ha^{-1}, with mean value of 400.55, 382.89 and 347.75 kg ha^{-1} respectively, while as in sub-surface soils it varied with statistical range (95% CI) from 51.80 to 562.98, 145.76 to 402.42 and 142.25 to 221.86 kg ha^{-1}, with mean value of 307.39, 274.09 and 182.06 kg ha^{-1} respectively (Table-2). The available nitrogen status was medium and significantly higher value was observed in high density apple orchards located at high altitude followed by mid and low altitude. This with altitude may be attributed to the altitudinal and climatic variations responsible for the accumulation of higher organic matter content in high altitude. These results are in agreement with those of Mushki (2013) [34], Dar *et al.* (2012) [12]. The available nitrogen was higher in surface soils which showed a linear decreasing trend with an increase in soil depth in all the three altitudes. Similar results were reported by Naidu and Sireesha (2013) [35] and Wani *et al.* (2017) [6] who attributed it to the favorable environmental conditions for mineralization at the surface than sub-surface soils and the depletion of nitrogen by crops supplemented through external nitrogenous source like fertilizers during crop cultivation.

Available phosphorus (P)

Perusal of data in Table-2 revealed that available phosphorus in the surface soils of high, mid and low altitude soils ranged statistical (95% CI) from17.00 to 39.52, 7.13 to 18.06 and 10.52 to 12.13 kg ha^{-1} with mean value of 19.21, 14.60 and 14.54 kg ha^{-1} respectively, while as, in the sub-surface soils it varied (95% CI) from 16.23 to 34.46, 5.91 to 10.78 and 7.44 to 8.34 kg ha^{-1} with mean value of 11.65, 8.35 and 8.62 kg ha^{-1} respectively. In general, the soils of high altitude showed higher levels of available phosphorus content followed by mid and low altitudes soils which could be attributed to favorable soils reaction and high organic matter leading to the formation of organophosphate complexes and coating of iron and aluminum particles by humus. This is supported by the research work of Akhtar (2005) [2], Dar *et al.* (2012) [12]. The available phosphorus was maximum in surface layers and it exhibited a decreasing trend with an increase in soil depth, which may be due to variation in amount of organic matter and soil reaction. Similar results about soils of Kashmir were also reported by Wani (2001) [55] and Dar *et al.* (2009) [3]. The lower phosphorus content in sub-surface soils could also be attributed to the fixation of P by clay-minerals and oxides of iron and aluminium (Thangasamy *et al.*, 2005; Khanday, 2013; Maqbool *et al.*, 2017) [50, 24, 29].

Available potassium (K)

Examination of the data in Table-2 showed that available potassium content in the surface soils of high, mid and low altitude high density apple orchards varied with the statistical range (95% CI) from 335.58 to 362.91, 172.05 to 502.16 and 266.82 to 297.42 kg ha^{-1} with mean value of 352.14, 337.11 and 282.12 kg ha^{-1} respectively whereas, in sub-surface soils its statistical range (95% CI) varied from 338.42 to 349.22, 276.96 to 330.21 and 241.08 to 266.51 kg ha^{-1} with mean value of 343.82, 303.59 and 253.79 kg ha^{-1} respectively. The available potassium was higher in surface soils than at sub-surface soils in all orchards located in three different altitudes. The available potassium showed significant variation with altitude with higher value in higher altitude. This higher status in surface soils and in higher altitude soils might be attributed to more intense weathering (Kirmani, 2004) [25], release of labile K from organic residues, application of K fertilizers (Naidu and Sireesha, 2013) [35] and upward translocation of K along with capillary rise of ground water (Sharma and Kumar, 2003) [46]. Furthermore, the available potassium revealed decreasing trend with depth except P_5 and P_{10} which showed an irregular trend with soil depth. This erratic distribution of available potassium may be due changes in weathering intensity during soil forming processes with climate and altitudinal gradients and was supported by Najar *et al.* (2009) [38], Bhat (2010), Dar *et al.* (2013) [13] and Wani *et al.* (2017) [6].

Table 2: Macro-nutrient status of High density Apple orchard soils of north Kashmir

Profile	Depth (cm)	N	P	K	Ca	Mg	S
		(kg ha^{-1})			(ppm)		
High Altitude							
P_1	0-30	400.55	19.21	352.14	1800.00	248.40	13.07
	30-60	327.51	16.11	344.25	1900.00	260.12	11.00
	60-90	287.28	7.12	343.40	1980.00	261.28	9.12
Surface	Mean	400.55	19.21	352.14	1800.00	248.40	13.07
	95% CI	62.55-589.22	17.00-39.52	335.58-362.91	1334.64-2156.33	265.65-300.12	1.95-25.61
Sub-surface	Mean	307.39	11.65	343.82	1940.00	260.70	10.06
	95% CI	51.80-562.98	16.23-34.46	338.42-349.22	1431.75-2448.24	253.33-268.06	1.88-22.00
Mid Altitude							
P_2	0-30	390.14	17.03	324.12	2130.00	262.44	11.05
	30-60	370.68	10.21	304.70	2250.00	270.00	9.52
	60-90	205.61	7.12	288.00	2300.00	271.89	8.11
P_3	0-30	375.65	12.17	350.10	2570.00	287.61	9.54
	30-60	310.54	9.00	326.50	2571.00	330.20	8.00
	60-90	209.55	7.07	295.17	2580.00	339.21	7.52
Surface	Mean	382.89	14.60	337.11	2350.00	275.02	10.29
	95% CI	290.83-474.95	7.13-18.06	172.05-502.16	445036-5145.36	115.11-434.93	0.70-19.88
Sub-surface	Mean	274.09	8.35	303.59	2425.25	302.82	8.28
	95% CI	145.76-402.42	5.91-10.78	276.96-330.21	2152.80-2680.69	243.94-361.70	6.91-9.65
Low Altitude							
P_4	0-30	375.14	15.44	277.14	1700.00	227.00	10.88
	30-60	259.35	8.43	254.91	1880.00	225.85	9.52
	60-90	121.08	7.10	224.10	1997.00	241.10	7.55
P_5	0-30	328.11	17.79	268.00	1800.00	235.10	10.74
	30-60	265.82	9.15	269.72	2000.00	247.62	8.52
	60-90	117.58	7.91	256.10	2120.00	254.13	7.00
P_6	0-30	307.48	12.88	261.85	2100.00	254.63	9.19
	30-60	212.66	8.86	250.10	2311.00	266.50	7.50
	60-90	109.74	7.25	243.58	2350.00	273.12	6.30
P_7	0-30	355.55	12.09	260.55	2401.00	286.95	9.27
	30-60	294.02	11.07	225.09	2440.00	288.52	5.09
	60-90	104.51	7.11	218.08	2480.00	290.77	4.58
P_8	0-30	358.84	16.77	308.25	2220.00	265.00	10.97
	30-60	278.04	11.16	294.06	2325.00	272.00	7.22
	60-90	119.51	8.27	245.26	2400.00	281.09	6.08

P_9	0-30	307.11	10.99	312.52	2215.00	249.01	10.08
	30-60	285.12	8.65	290.41	2300.00	251.00	7.00
	60-90	121.05	7.58	267.77	2355.00	240.99	6.02
P_{10}	0-30	375.11	12.10	275.24	2395.00	283.10	9.02
	30-60	91.56	8.08	281.57	2382.00	282.11	6.91
	60-90	131.52	6.22	201.14	2390.00	284.99	6.12
P_{11}	0-30	394.00	17.19	301.02	1900.00	235.00	11.01
	30-60	258.65	12.05	282.38	2100.00	252.15	9.21
	60-90	124.99	7.73	256.10	2200.00	268.11	7.53
P_{12}	0-30	328.42	15.68	274.58	2080.00	263.41	10.81
	30-60	280.00	12.21	262.81	2100.00	274.00	7.65
	60-90	101.92	6.33	245.16	2228.00	282.67	5.14
Surface	Mean	347.75	14.54	282.12	2090.11	255.46	10.21
	95% CI	323.66-371.83	10.52-12.13	266.82-297.42	1898.95-2281.27	239.17-271.76	7.55-10.23
Sub-surface	Mean	182.06	8.62	253.79	2242.11	265.37	6.94
	95% CI	142.25-221.86	7.44-8.34	241.08-266.51	2156.09-2328.12	255.91-274.83	6.27-7.61
Surface	Mean	359.05	14.89	298.91	2125.07	259.15	10.43
	95% CI	337.06-378.95	10.87-13.02	276.35-317.89	1973.58-2294.91	245.08-271.18	8.23-10.54
Sub-surface	Mean	209.40	8.79	270.29	2252.45	272.21	7.43
	95% CI	170.63-245.05	7.57-8.57	253.82-285.37	2162.58-2329.50	260.41-282.04	6.76-8.08
Surface Sub-surface	C.D ($p \leq 0.05$)	12.97	0.29	4.52	14.03	3.35	0.22

CI = Confidence interval, C.D = Critical deference

Available calcium (Ca)

The available calcium content varied with the statistical range (95% CI) from 1334.64 to 2156.33, 445036 to 5145.36 and 1898.95 to 2281.27 ppm with mean value of 1800.00, 2350.00 and 2090.11 ppm in the surface soils of high, mid and low altitude, respectively whereas, it varied with the statistical range (95% CI) from 1431.75 to 2448.24, 2152.80 to 2680.69 and 2156.09 to 2328.12 ppm with mean value of 1940.00, 2425.25 and 2242.11 ppm in sub-surface soils respectively as shown in Table-2. These values are in agreement with those of Wani (2001) [55] and Dar (2009) [3] while studying apple and pear orchard soils respectively. The available calcium content varied significantly with altitude and maximum content in the soils of mid altitude which could be due to calcareous parent material. These finding corroborates with the results of Wani *et al.* (2017) [6]. The available calcium revealed an increasing trend with an increase in depth in all three altitudes.

Available magnesium (Mg)

The data presented in the Table-2 revealed that available magnesium in the surface soils of high mid, and low altitude varied with the statistical range (95% CI) from 265.65 to 300.12, 115.11 to 434.93 and 239.17 to 271.76 ppm with mean value of 248.40, 275.02 and 255.46 ppm respectively and in sub-surface soils it ranged statistically (95% CI) from 253.33 to 268.06, 243.94 to 361.70 and 255.91 to 274.83 ppm with mean value of 260.60, 302.82 and 265.37 ppm respectively. These values are in agreement with those of Najar (2002) [37] and Wani *et al.* (2016) [54] while working on soils of Kashmir under apple and pear orchards, respectively. The available magnesium did not exhibit any consistent trend with soil depth which can be attributed to stratification of these soils. This is in conformity with the findings of Najar *et al.* (2009) [38] and Dar *et al.* (2012) [12]. The higher contents of available magnesium in surface and sub-surface soils were found in the high density apple orchard soils of mid altitude followed by low and high altitude soils respectively may be due to high amount calcium carbonate and favorable pH.

Available sulphur (S)

Perusal of data as shown in Table-2 indicated that available sulphur ranged statistically (95% CI) from 1.95 to 25.61, 0.70 to 19.88 and 7.55 to 10.23 ppm with mean value of 13.07, 10.29 and 10.21ppm in surface soils of high, mid and low altitude respectively, while as in sub-surface soils it ranged statistically (95% CI) from 1.88 to 22.00, 6.91 to 9.65 and 6.27 to 7.61 ppm with mean value of 10.06, 8.28 and 6.94 ppm in high, mid and low altitude, respectively. These values are in agreement with those of Najar (2002) [37] and Dar (2009) [3]. The available sulphur showed a decreasing trend with an increase in its vertical distribution. It may be due to increasing pH with depth and decrease of organic carbon with depth. The available sulphur in surface soils was more in comparison to sub-surface soils and highest value recorded in high altitude soils. This could be attributed due to higher amounts of organic matter content of the surface soils and of high altitude, as indicated by positive correlation of available sulphur with organic carbon as shown in Table-3. This is supported by the findings of Panday *et al.* (2000) [42], Dar *et al.* (2013) [13] and Wani *et al.* (2017) [6].

Relationship between physico-chemical properties and available nutrients

Soil reaction (pH)

The pH of surface soils had significant negative correlation with nitrogen (r =-0.557*), phosphorus (r =-0.595*), sulphur (r =-0.722**), zinc (r =-0.884**), copper (r =-0.933**), manganese (r =-0.687*) and iron (r =-0.847**). On the other hand, it showed significant positive correlation with calcium (r = 0.821**) and magnesium(r= 0.800**) only. All other elements revealed non-significant negative correlation with pH. Similarly, sub-surface soils had significant and negative correlation with sulphur (r =-0.630**), zinc (r =-0.783**), copper (r =-0.837**), manganese (r =-0.541**) and iron (r =-0.777**). Significant positive correlation was found with calcium (r = 0.722**) and magnesium (r = 0.615**) The relationship of pH with all other nutrients was observed to be negative but non-significant (Table-3). A negative relationship between soil pH and available nitrogen is confirmed by the findings of Wani (2001) [55], Akhtar (2005) [2] and Dar *et al.* (2012) [12]. The availability of phosphorus decreases with increase in soil pH because of its conversion into insoluble tricalcium phosphates. Increase in soil pH with depth leads to fixation of phosphorus in different forms of apatite whereas substantial decrease in pH fixes it as aluminium phosphates (Al-PO_4^-) thereby rendering it unavailable. A significant negative relationship between soil pH and available phosphorus has been reported by Dar *et al.* (2012) [12] and Maqbool *et al.* (2016) [30]. The relationship between pH and available potassium was in line with the findings of Narboo (1994). The increase in calcium with the increase in pH is quite obvious because of basic nature of calcium. A positive and significant relationship between soil pH and available calcium is supported by the findings of Kumar and Babel (2011), Bhat *et al.* (2017) Wani *et al.* (2017) [6].

Electrical conductivity (EC)

Electrical conductivity of surface soils showed negative non-significant correlation with nitrogen, phosphorus, sulphur, zinc, copper, manganese and iron. While as positive non-significant correlation with potassium, calcium, magnesium similarly Electrical conductivity of sub-surface soils showed non-significant negative correlation with nitrogen, phosphorus, potassium, Sulphur while as calcium (r = 0.518*) and magnesium (r = 0.491*) revealed significant positive correlation with Electrical conductivity respectively. Maqbool *et al.* (2016) [30] while studying different land use systems found significant positive correlation between EC with Ca and Mg, similar finding was observed by Tuma *et al.* (2013) [52].

Table 3: Correlation coefficients (r) of soil physico-chemical characteristics with available nutrients in high density apple orchard soils of north Kashmir

Soil available Nutrient	Surface soils (0-30)				Sub-surface soils (30-90)			
	pH	EC	OC	$CaCO_3$	pH	EC	OC	$CaCO_3$
N	-0.557*	-0.347	0.595*	0.193	-0.284	-0.024	0.531*	-0.046
P	-0.595*	-0.053	0.819**	-0.168	-0.311	-0.274	0.698**	-0.220
K	-0.219	0.039	0.516	0.249	-0.175	-0.030	0.306	-0.096
Ca	0.821**	0.436	-0.398	0.748**	0.722**	0.518*	-0.134	0.679**
Mg	0.800**	0.477	-0.238	0.432	0.675**	0.491*	-0.229	0.403
S	-0.722**	-0.169	0.444	0.350	-0.660**	-0.143	0.255	-0.341

Organic carbon

Soil organic carbon showed significant positive correlation with available nitrogen (r = 0.595*) and phosphorus (r = 0.819**) and non-significant positive correlation with all other nutrients except calcium and magnesium where non-significant negative correlation was observed both in surface and sub-surface soils. The significant and positive relationship between organic carbon and available nitrogen could be attributed to the association of nitrogen with organic matter and adsorption of NH_4-N by humus complexes in soils (Dar (2009) [3]. Similar results have been reported by Singh and Rathore (2013) [47], Adak *et al.* (2014) [1] and Maqbool *et al.* (2017) [29]. The increase in availability of nitrogen, phosphorus, sulphur, copper, iron and manganese may be attributed to the release of these elements from organic complexes as well as from the weathering of minerals containing these elements due to acidulating action of organic matter. A significant and positive correlation of organic carbon and available phosphorus indicates that organic matter is a major limiting factor for nitrogen, phosphorous and potassium in soil as was also reported by Panday *et al.* (2000) [42], Fida *et al.* (2011) [16], Singh and Rathore (2014) [47] and Adak *et al.* (2014) [1]. The positive relationship between organic carbon and available potassium is in conformity with the findings of Dar (2012) [12], Fida *et al.* (2011) [16] and Wani *et al.*, 2017) [6].

Calcium carbonate ($CaCO_3$)

Perusal of the data in Table-3, revealed that calcium carbonate showed positive significant correlation with calcium (r = 0.748*). Non-significant but positive correlation with nitrogen, potassium, magnesium and sulphur while as phosphorus showed non-significant but negative correlation with calcium carbonate content. In sub-surface soils calcium carbonate showed non-significant but negative correlation with nitrogen, phosphorous, potassium and Sulphur. Significantly positive relationship was observed with calcium (r = 0.679**). The non-significant relationship between calcium carbonate and nitrogen was also observed by Minhas and Bora (1982). Results showed that calcium carbonate exhibited non-significant correlation with available phosphorus and potassium. Similar finding was earlier reported by Akhtar (2005) [2], Maqbool *et al.* (2016) [30].

Leaf macro-nutrients

Nitrogen (N)

The nitrogen content in leaves of high density apple ranged from 2.02 to 3.10, 1.74 to 2.51 and 2.13 to 2.31 per cent at 95%CI with mean values of 2.50, 2.13 and 2.03 per cent in high, mid and low altitudes respectively (Table-4). Similar range of leaf nitrogen was reported by Dar (2009) [3] and Wani *et al.* (2017) [6]. The high density apple leaves showed sufficient nitrogen status. This could be attributed to the annual application of manures and fertilizers and decomposition of natural and added organic matter together with biological nitrogen fixation. These results are in accordance with those of Amiri and Fallahi (2009) [3] and Wani *et al.* (2017) [6]. The leaf nitrogen content exhibited a significant difference with the altitude with higher amount found in high altitude orchards, which may be due to higher availability of nitrogen and increased photosynthetic efficiency, because increased photosynthesis increases the uptake (Faust, 1989) [15]. This is in agreement with the findings of Bist and Yadav (2000) [7], Lulu *et al.* (2017) [27] while working on apple and pear orchards, respectively.

Phosphorus (P)

Perusal of data in Table-4 revealed that leaf phosphorus content in high, mid and low altitude ranged from 0.10 to 0.61, 0.11 to 0.57 and 0.09 to0.49 per cent with the mean value of 1.18, 1.17 and 0.12 per cent, respectively. These results are in agreement with those of Dar (2009) [3]. The high density apple leaves showed sufficient phosphorus status in three altitudes. This supported by the findings of Najar (2002) [37], while working on apple orchards. The leaf phosphorus content revealed significant variation among the orchards of the three altitudes with highest value in high altitude soils, which may be due to variation in soil, climatic conditions, elevation and other associated features. This is in line with the results of Xu *et al.* (2015) [59].

Potassium (K)

The potassium content in leaves of high density apple orchards in high, mid and low altitude varied from 1.07 to 2.41, 0.85 to 2.35 and 1.31 to 1.73 per cent at 95% CI with mean value of 1.67, 1.64 and 1.61 per cent, respectively (Table-4). Presence of leaf potassium content of the similar magnitude have been observed by Dar (2009) [3]. The leaf potassium content varied significantly in the orchards of three altitudes with highest content in high altitude, which could be due to variation in soil potassium and other associated features. This is supported by the findings of Fallahi (2010) [14].

Table 4: Macro-nutrient content (%) of High Density Apple leaves on dry weight basis in north Kashmir

Profile /location	N	P	K	Ca	Mg	S
High Altitude						
P_1 Sambler Bandipora	2.50	0.18	1.67	1.36	0.25	0.25
Mean	2.50	0.18	1.67	1.36	0.25	0.25
CI (95%)	2.02-3.10	0.10-0.61	1.07-2.41	0.80-2.00	0.02-0.91	0.01-1.00
Mid Altitude						
P_2 Kunzer Baramulla	2.30	0.15	1.64	1.41	0.37	0.23
P_3 Parihaspora Baramulla	1.96	0.12	1.65	1.80	0.45	0.20
Mean	2.13	0.17	1.64	1.60	0.41	0.21
95% CI	1.74-2.51	0.11-0.57	0.85-2.35	1.57-1.95	0.17-0.52	0.02-0.40
Low Altitude						
P_4 Unagam Bandipora	2.12	0.14	1.68	1.41	0.36	0.22
P_5 Upper kunan Bandipora	2.04	0.13	1.72	1.48	0.36	0.23
P_6 Lodder Baramulla	2.09	0.12	1.71	1.52	0.37	0.21
P_7 Chooru Baramulla	1.93	0.11	1.48	1.70	0.41	0.23
P_8 Mazibug Baramulla	2.09	0.14	1.67	1.46	0.38	0.21
P_9 Sopore Baramulla	2.08	0.12	1.60	1.48	0.31	0.21
P_{10} Pandithpora Kupwara	1.90	0.10	1.35	1.72	0.39	0.21
P_{11} Chougul Kupwara	2.10	0.15	1.62	1.54	0.37	0.24
P_{12} Jalalabad Baramulla	1.98	0.13	1.66	1.56	0.31	0.23
Mean	2.03	0.12	1.61	1.54	0.36	0.22
95% CI	2.13-2.31	0.09-0.49	1.31-1.73	1.23-1.74	0.26-0.40	0.20-0.24
Mean	2.22	0.15	1.50	1.52	0.34	0.22
5% CI	2.14-2.28	0.14-0.51	1.64-1.79	1.66-1.75	0.27-0.31	0.20-0.23

CI = Confidence interval, C.D = Critical deference

Calcium (Ca)

Examination of data in Table-4 indicated that leaf calcium content ranged from 0.80 to 2.00, 1.57 to 1.95 and 1.23 to 1.74 per cent at 95% CI with mean value of 1.36, 1.60, and 1.59 per cent in high, mid and low altitude, respectively. Woodbridge and Lahsheen (1960) [58] reported similar findings. All leaf samples under study were found to be sufficient in calcium. These results are in conformity with the findings of Najar (2002) [37]. The leaf calcium content exhibited significant variation amongst orchards at different altitudes with maximum amount recorded in mid altitude orchards. This could be due to available calcium and other associated features like pH, moisture, nutrient interaction, high calcium carbonate root stock effect etc., affecting its uptake. These results are in agreement with the findings of Milošević (2015) [31] and Wani *et al.* (2017) [6] while working on apple and pear orchards in Kashmir.

Magnesium (Mg)

The magnesium content in leaves of high density apple orchards in high, mid and low altitude varied from 0.02 to 0.91, 0.17 to 0.52 and 0.26 to 0.40 per cent at 95% CI with mean value of 0.25, 0.41 and 0.36 per cent respectively, as shown in Table-4. These values are in agreement with the findings of Arora *et al.* (1992) [4] and Mushki (2013) [34]. The leaves showed sufficient magnesium status in all the high density apple orchards. The minimum and maximum mean leaf magnesium (0.41 and 0.25%) was recorded in mid altitude and high altitude respectively. The leaf magnesium showed significant variation among the orchards located in three altitudes. These are supported by the findings of Akhtar (2005) [2], Dar (2009) [3] and Mushki (2013) [34].

Sulphur (S)

Perusal of data in Table 4 revealed that leaf sulphur content of high density apple in high, mid and low altitude ranged from 0.01 to 1.00, 0.02 to 0.40 and 0.20 to 0.24 per cent at 95% CI with mean value of 0.25, 0.21 and 0.22 per cent, respectively. Adequate sulphur content in leaves were found with overall mean of 0.22 percent. The highest mean value (0.25%) and lowest mean value (0.21%) was recorded in high density apple orchards located in high altitude and mid altitude respectively. which could be attributed to adequate available sulphur in the soil and spraying of sulphur based fungicides against diseases and pests. This is supported by the findings of Wani (2001) [55]. The leaf sulphur exhibited significant variation among the orchards of different altitudes. This is in conformity with the findings of Wani (2001) [55] and Dar (2009) [3].

Relationship between soil and leaf nutrients

The relationship between the available nutrient contents in soil and leaf nutrient contents of high density apple orchards of district of north Kashmir, presented in Table-5 is discussed below.

The nitrogen content in leaves of high density apple showed positive significant correlation with the available nitrogen content in surface and sub-surface soils, respectively as shown in Table-5. These results are in line with the findings of Jivan (2014) [22]. The correlation coefficients of phosphorus content in the high density apple leaves were found to be significant positive with respective to surface and sub-surface soil depths. These are supported by the results of Akhtar (2005) [2] and Dar (2009) [3]. The leaf potassium content exhibited non-significant and positive relation with the available soil potassium content. Najar (2002) [37], Dar *et al.*

(2013) [13] and Wani *et al.* (2016) [54] have reported similar results.

Table 5: Correlation coefficients (r) between available soil nutrients and leaf nutrients in high density apple orchard of north Kashmir

S. No.	Nutrient	Surface soils (0-30 cm)	Sub-surface soils (30-90 cm)
1	N	0.675**	0.562*
2	P	0.605**	0.558*
3	K	0.460	0.421
4	Ca	0.602*	0.751**
5	Mg	0.516	0.512
6	S	0.454	0.520

*Significant at 5 per cent level and
**Significant at 1 per cent level

The foliar calcium content revealed significant and positive correlation with available calcium in surface soils as well as sub surface soils, Such relationship was also observed by Basso *et al.* (1990), Singh and Bhandari (1992) [48], Najar (2002) [37] and Dar (2009) [3]. Non-significant relation was observed between leaf magnesium and available magnesium in our study. Sharma and Bhandari (1992) [48], Najar (2002) [37], Dar (2009) [3] also found similar relationship between the two for any of the soil depths. The sulphur content in the leaves exhibited non-significant but positive relationship with available sulphur content in both surface and sub-surface soil depths. This has been supported by the findings of Najar (2002) [37] for apple and later by the working of Dar (2012) [12] in pear in Kashmir Valley.

Fruit yield

Examination of data in Table-6 indicates that fruit yield of HDP apple in high, mid and low altitude varied from 25.12 to 33.84, 23.99 to 28.21 and 20.329 to 27.253 t ha^{-1} at 95% CI with mean value of 29.00, 25.60 and 25.56 tons per hectare. A significant variation was observed in fruit yield among the orchards located in three altitudes, which could be due to variation in nutrient status of orchards under study. This is supported by the findings of Pandey *et al.* (2004), Sharma *et al.* (2010) and Insha *et al.* (2018).

Table 6: Average fruit yield (t ha^{-1}) of high density apple in north Kashmir

Location	Yield
High Altitude (H)	
P_3 Sambler Bandipora (H-1)	29.00
Mean	29.00
95% CI	25.12-33.84
Mid Altitude (M)	
P_5 Kunzer Baramulla (M-1)	26.204
P_{12} Parihaspora Baramulla (M-2)	25.006
Mean	25.60
95% CI	23.99-28.21
Low Altitude (M)	
P_1 Unagam Bandipora (L-1)	25.555
P_2 Upper kunan Bandipora (L-2)	27.873
P_4 Lodder Baramulla (L-3)	20.105
P_6 Chooru Baramulla (L-4)	27.010
P_7 Mazibug Baramulla (L-5)	24.024
P_8 Sopore Baramulla (L-6)	19.012
P_9 Pandithpora Kupwara (L-7)	26.602
P_{10} Chougul Kupwara (L-8)	30.348
P_{11} Jalalabad Baramulla (L-9)	25.597
Mean	25.56
95% CI	20.32-27.25
Mean	26.72
95% CI	21.133-30.922

CI = Confidence interval

Relationship between leaf and soil nutrients with the fruit yield

Leaf nutrients and fruit yield

Among the macronutrients, nitrogen, potassium exhibited a positive and significant relationship with the fruit yield. (Table-7), this was in conformity with the findings of Kumar and Chandel (2004), Dar (2009) [3] and Bhat *et al.* (2017). A positively significant relation of leaf sulphur and yield was recorded, this could be due to its role in plant metabolism especially for enhancing biosynthesis of organic food and cell division. This is supported by the findings of Mostafa and Kader (2006) [33] and Rongfei *et al.*, 2017 [44], who reported that increased sulphur application significantly increased leaf sulphur content and also increases significantly the fruit length, diameter, weight, total soluble solids, total sugars and yield significantly. This is also in agreement with the findings of Mansour *et al.* (2008) [28] while working on pear.

Table 7: Correlation coefficients (r) of leaf and soil nutrients with the fruit yield in high density orchards of north Kashmir

S. No.	Nutrient (Variable)	Leaf nutrient (r)	Soil nutrients (r)
1	Nitrogen	0.623*	0.697*
2	Phosphorous	0.498*	0.457*
3	Potassium	0.197	0.151
4	Calcium	0.040	0.421*
5	Magnesium	0.035	0.215
6	Sulphur	0.646*	0.328

Available soil nutrients and fruit yield

Among the macronutrients, available soil nitrogen, phosphorous and calcium showed significant positive relationship with fruit yield in surface soil (Table-7) while as rest nutrients showed positive but non-significant correlation with yield. This could be due to its effect of nitrogen on cell division and cell elongation leading to development of large and efficient leaf surface thereby increase photosynthetic area of plants and in turn yield get increased, phosphorus increases the root development thereby increasing area of absorption of nutrients which in turn might have resulted in increase in yield. Calcium helps in stimulation of buds, flower initiation, flower formation and fruit set with significant increase in yield attributes. These results are supported by the findings of Kumar and Chandel (2004), Akhtar (2005) [2] and Rather (2006) [43]

Conclusion

The available nutrients are by and large medium to high in high density apple orchard soils except sulphur which showed low to medium status. All the nutrients showed decreasing trend with altitude except calcium and magnesium which were higher in mid altitude soils. The leaf analysis indicate that high density apple orchards are having sufficient amounts of all nutrients. The effect of physico-chemical properties on the availability of nutrients revealed that nutrients showed positive relation with organic carbon. The study of relationship between available soil and leaf nutrients showed that plants absorb nutrients from both surface as well as sub-surface soils.

The variation observed between soil and leaf analysis indicates a need either to standardize the available nutrient extraction methods or change in critical limits suiting our conditions. A study of relationship of nutrient extracting capability of plant roots from different depths need to be studied in a detailed manner. Since most soil properties are dynamic in nature, detailed field and laboratory investigations be carried out on site specific approach to establish nutrient status and further strengthen the validity of the soil test-plant response relationship more accurately. quite useful for horticulturists for formulation of future research programme. The present study though first of its kind on high density apple orchards is expected to be quite useful for horticulturists for formulation of future research programme.

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